

# Estimating Chinese households' transport expenditure using non-transport survey data

Flexible demand systems, income, and the built environment

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iTEM4 workshop, day 2 — 31 October 2018





KUN MING ZHAN

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通信批发商城  
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昆明落实科学发展观 全面建设和谐社会

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7:00-23:00  
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7:00-23:00



Characterize **household demand** using the Exact affine Stone index (EASI) demand system & China Household Income Project (CHIP) survey data:

- More **flexible** link between transport spending and income.
- New **empirical facts** about HH transport spending; demand elasticities.
- Link demand to features of cities (the “**built environment**”).
- **Validation techniques** for flexible demands & partial-coverage data.

# China's urban passenger transport as a complex system

**Complex, large, interconnected, open, and socio-technical (CLIOS)<sup>1</sup>** transport systems → demand, ownership, motorization, & policy impacts arise in context.

## In China:

1. Diverse country with large rural/urban, province-to-province differences.
2. Rapid economic growth *and* transformation → changes in spending power.
3. Managed urbanization & expansion of transport infrastructure.

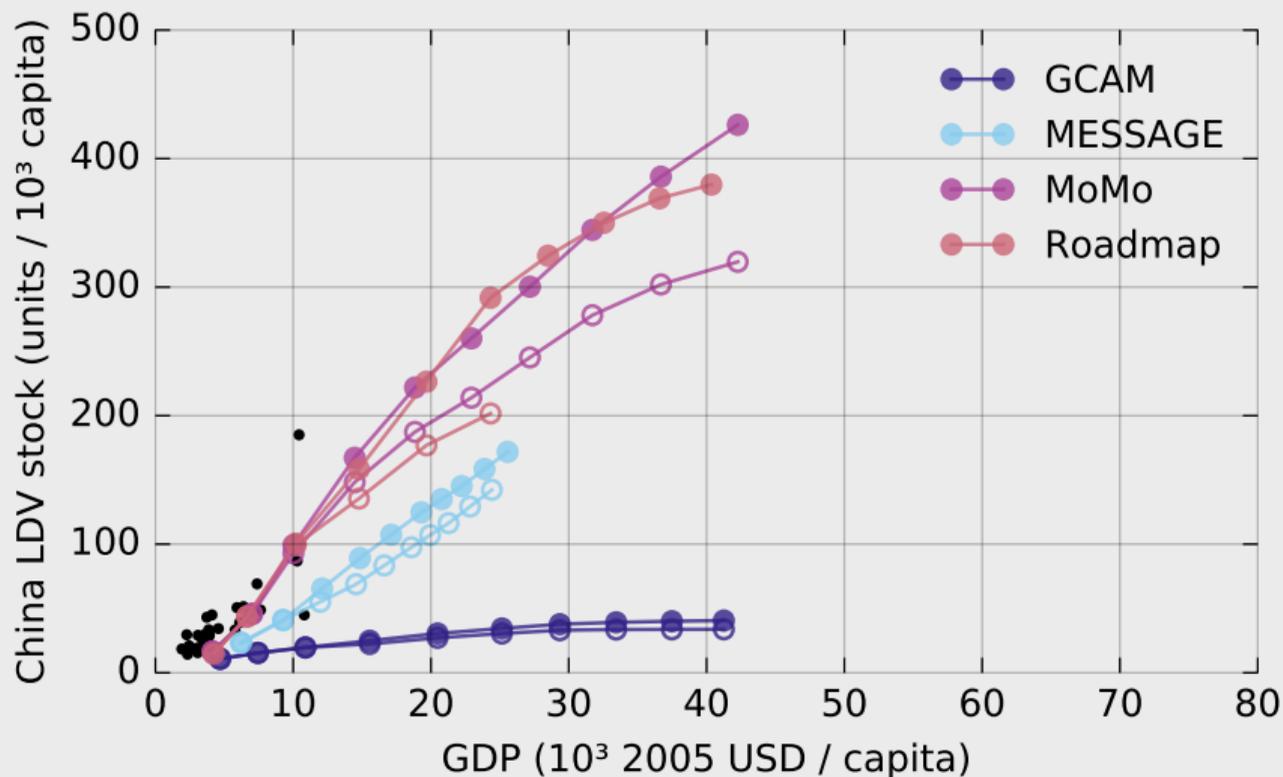
## Methodological challenges of rapid change:

- Heterogeneity below model resolution → exogenous parameter tuning.
- Major cities heavily studied → external validity concerns.
- Models encoding different demand logic → divergent projections.

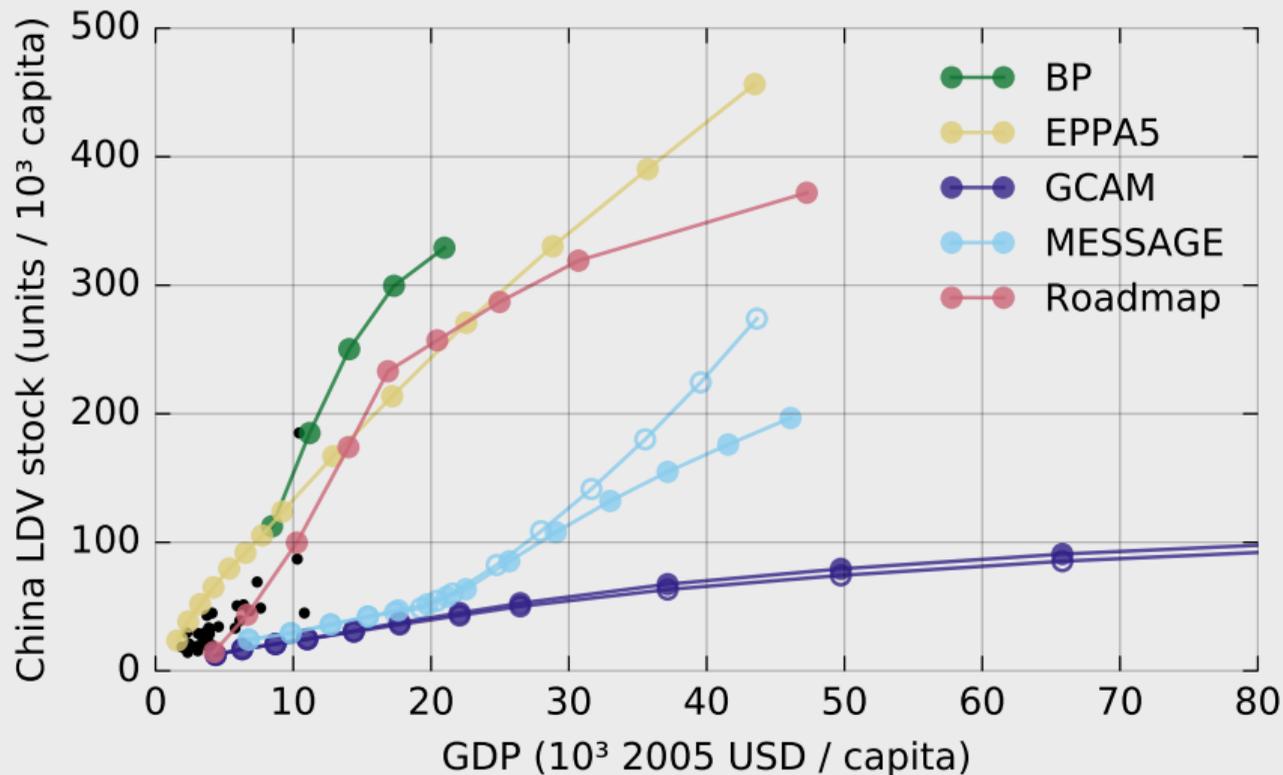
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<sup>1</sup>J. Sussman, Sgouridis, and Ward 2005; Mostashari and J. M. Sussman 2009.

# Structural uncertainty: China's motorization in global models (Yeh et al. 2016)



# Structural uncertainty: China's motorization in global models (Kishimoto et al. 2017)



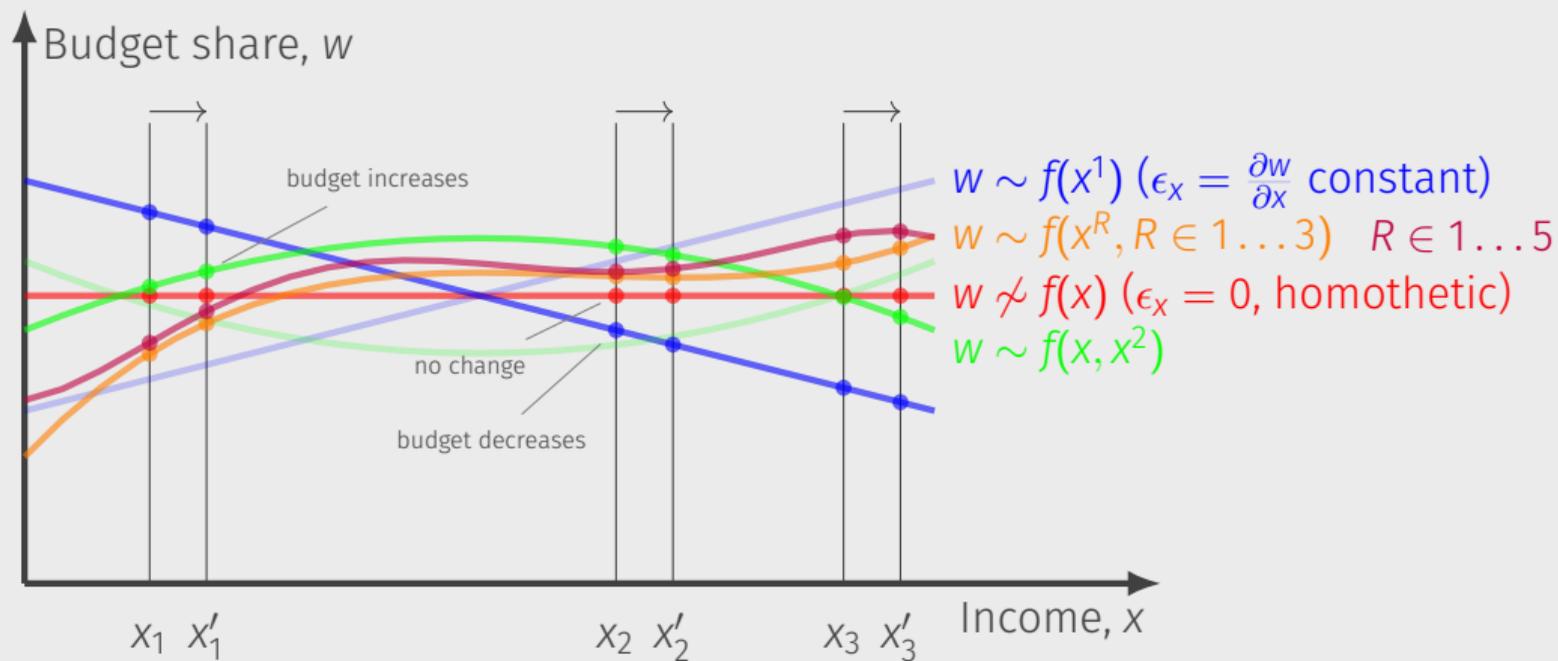
### What do newer, flexible econometric methods and non-transport survey data reveal about transport demand of Chinese households?

1. Develop a transport-focused application of Exact affine Stone index (EASI) demands to China Household Income Project (CHIP).
2. Estimate key demand quantities: the travel money budget (TMB), income elasticity of demand.
3. Compare with literature on budget shares; demand elasticities; travel and the built environment.

# Methodology

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# Flexibility in demand formulations



Many estimates on income-elasticities of demand for gasoline or vehicle-distance travelled (VDT) → at country level for China.<sup>2</sup>

- Controls for endogeneity of price/quantity.

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<sup>2</sup>McRae 1994; Goodwin, Dargay, and Hanly 2004; Dahl 2012; Lin and Zeng 2013; Arzaghi and Squalli 2015; Havranek and Kokes 2015.

<sup>3</sup>Deaton and Muellbauer 1980.

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<sup>5</sup>Caron, Karplus, and Schwarz 2017; Yang et al. 2017.

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Applications of AIDS<sup>3</sup> to transport in China → province-level, aggregate data.<sup>4</sup>

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Some flexible demand applications focused on energy goods (coal, electricity, gasoline) or food.<sup>5</sup>

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## Travel and the built environment

Extensive area of research<sup>6</sup> often based on local, tailored surveys ( $N \geq 1000$ ) and analysed using structural equation model (SEM)<sup>7</sup> or discrete choice models/random utility theory.<sup>8</sup>

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<sup>6</sup>Cervero and Murakami 2010; Gim 2012.

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Finely resolved independent concepts:

- **Density, diversity, design, destination accessibility, distance to transit.**
- Alternative measures of each.
- Measured from neighborhood/block-level to country level.

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Control for residential self-selection (endogeneity).<sup>9</sup>

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Household  $i$ 's budget share in category  $j \in J$ :

$$w_i^j = \sum_{r=0}^R \beta_{u,r}^j u_i^r + \sum_{t \in T} \beta_{z,t}^j z_{t,i} + \sum_{k \in J} \beta_{p,k}^j \ln p_i^k + e_i^j$$

expressed using:

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expressed using:

$u_i^r$   $R$ -order polynomial of utility,  $u$ .

Implicit utility estimated as  $\hat{y} = f(x, \mathbf{p}_i)$ .

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$\ln p_i^k$  Price indices for categories  $k \in J$ .

Parameters  $\beta_{u,r}^j, \beta_{z,t}^j, \beta_{p,k}^j$  estimated by iterated three-stage least squares (I3SLS).

Data

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**Household expenditures** ( $w^j, x$ ) from CHIP social science survey.<sup>10</sup>

- Annual consumption in 8+ categories in 1995, 2002, 2007.
- Income, location, demographics, social attributes, life events.
- Urban subsample: stratified by province/city,  $\sim 5000$  HH/wave.
- Freely available online.

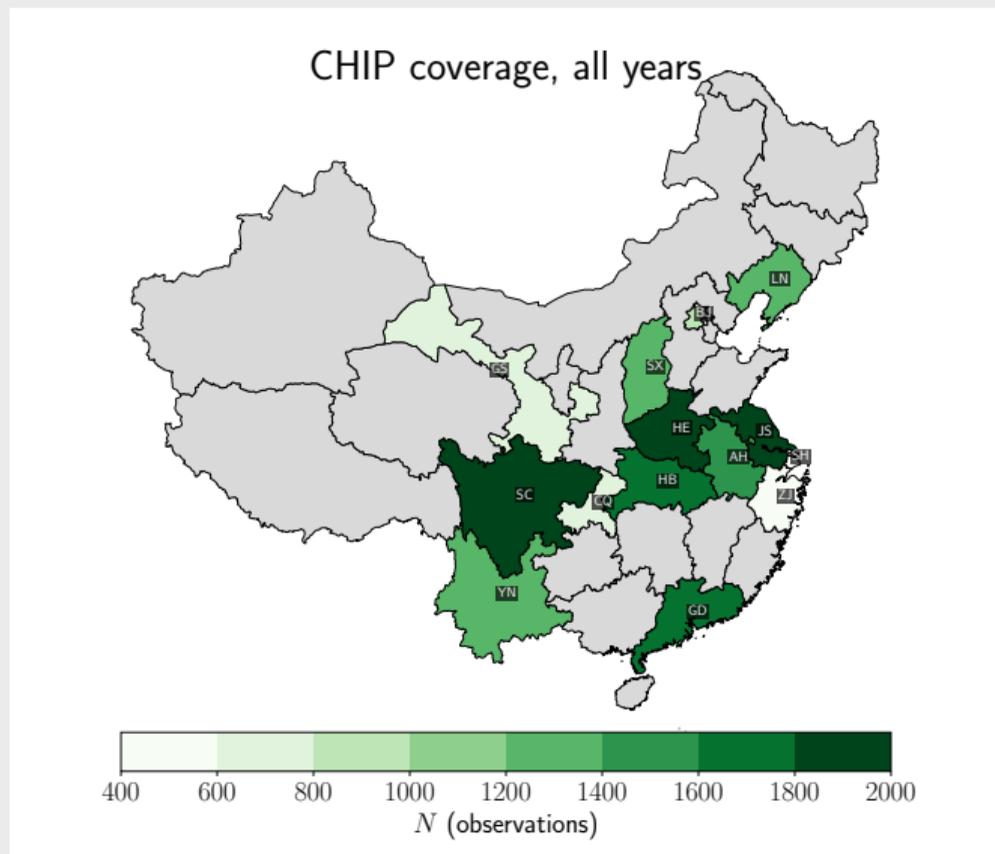
**City-level attributes** ( $z$ ) from “China Premium Database” published by CEIC Data (CEIC).

**Prices** ( $p$ ) from National Bureau of Statistics of China (NBSC).

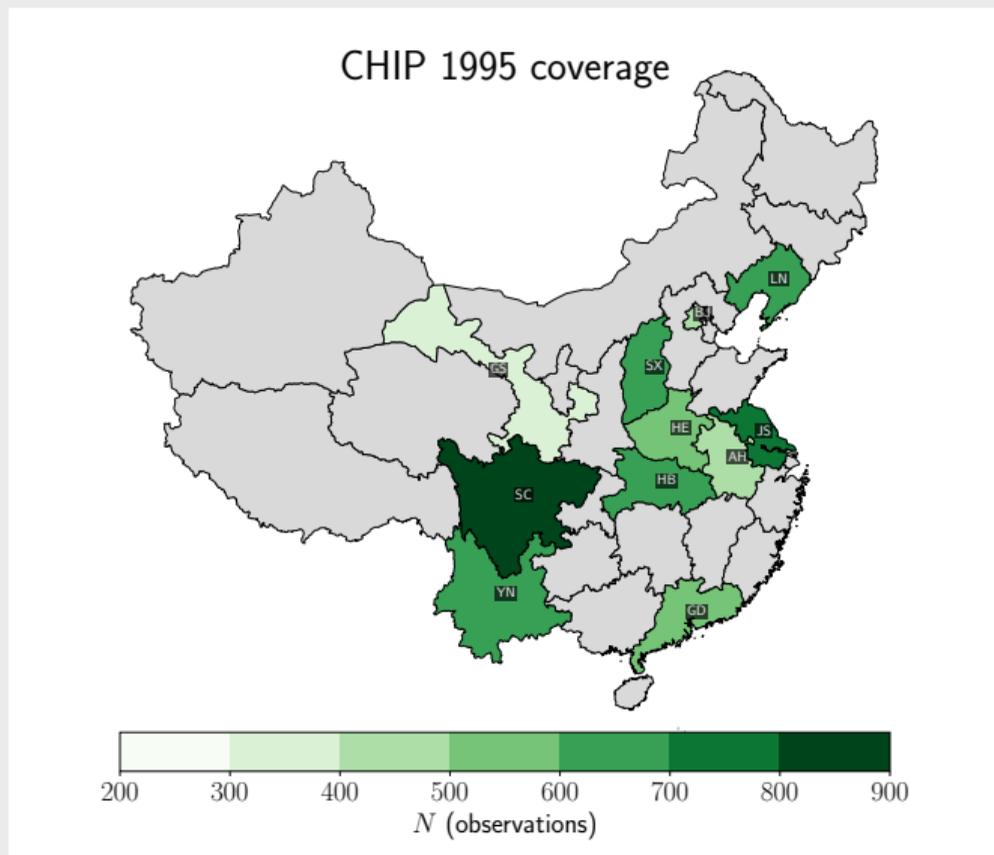
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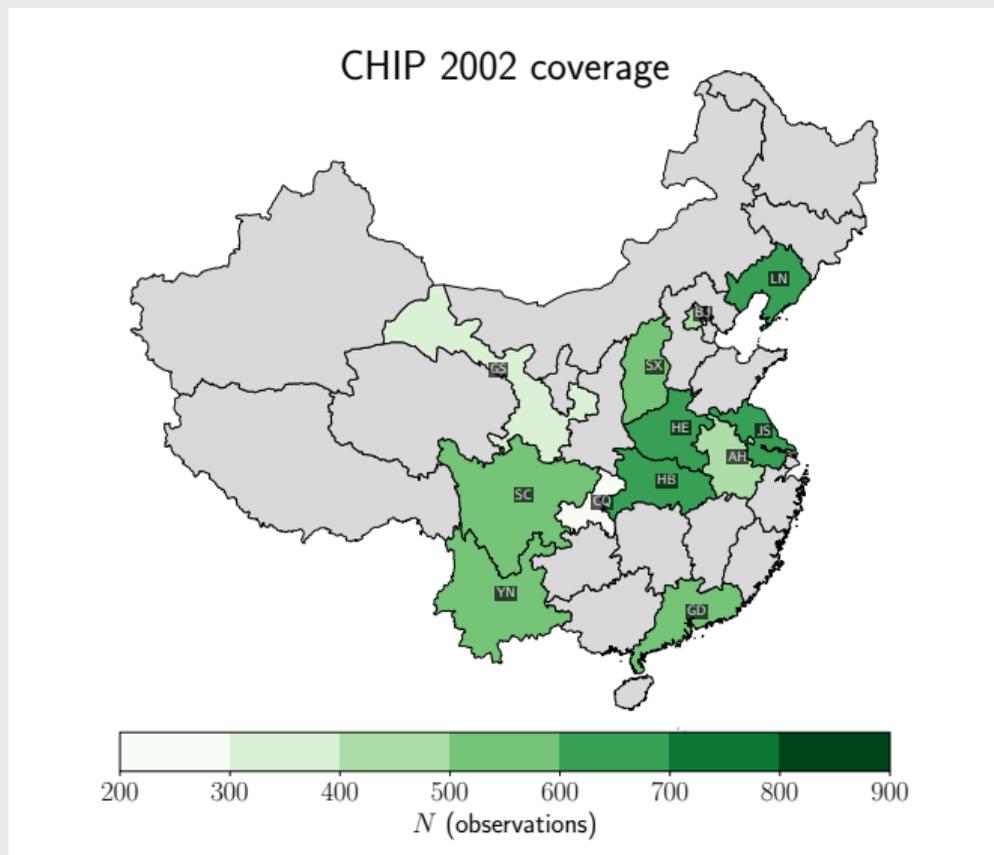
# CHIP survey covered households & cities in a shifting set of provinces



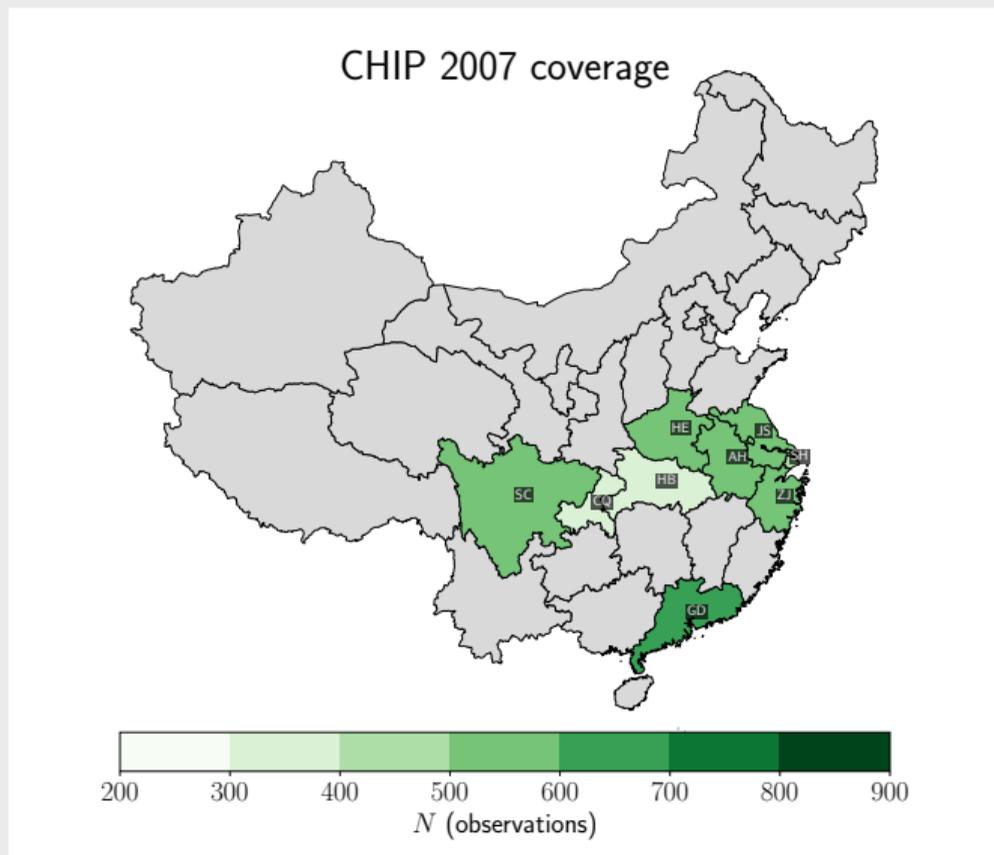
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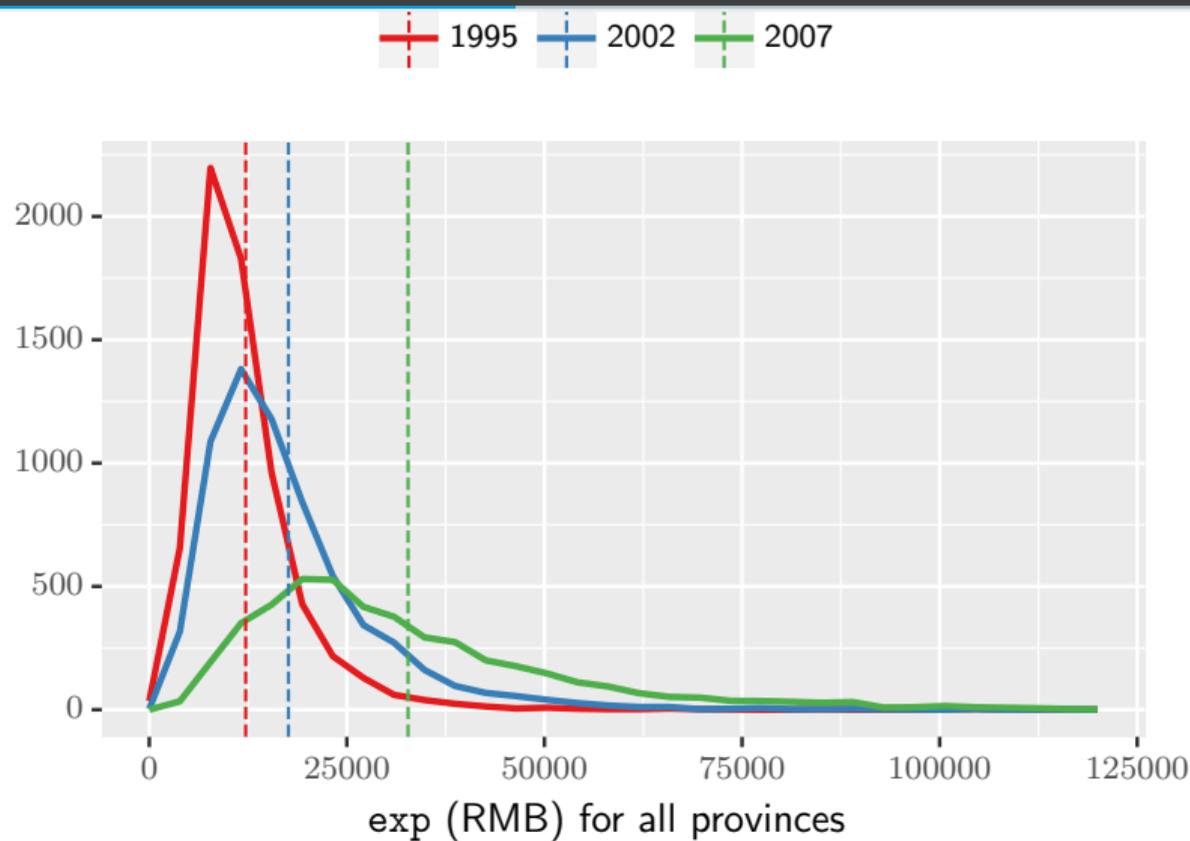
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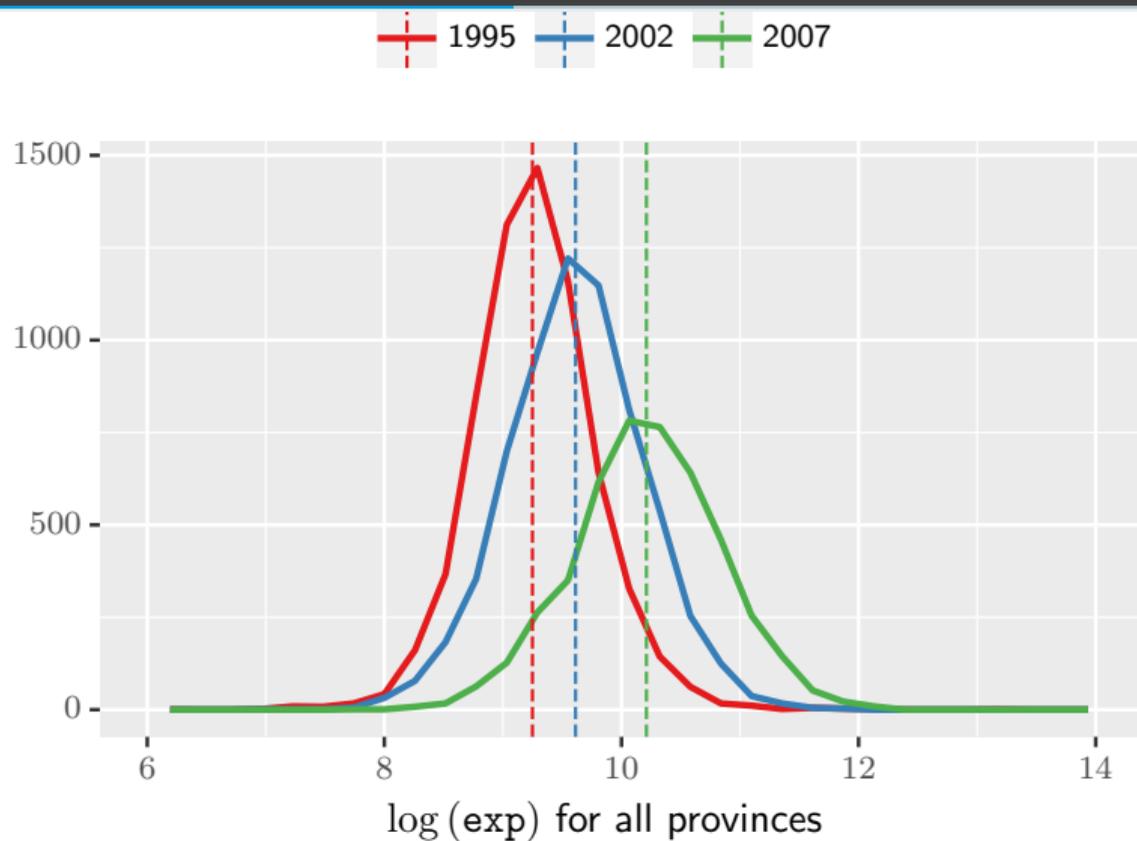
# Distribution of total household expenditure (x)



Income distribution shifts rightwards.

Coverage of x overlaps across CHIP waves.

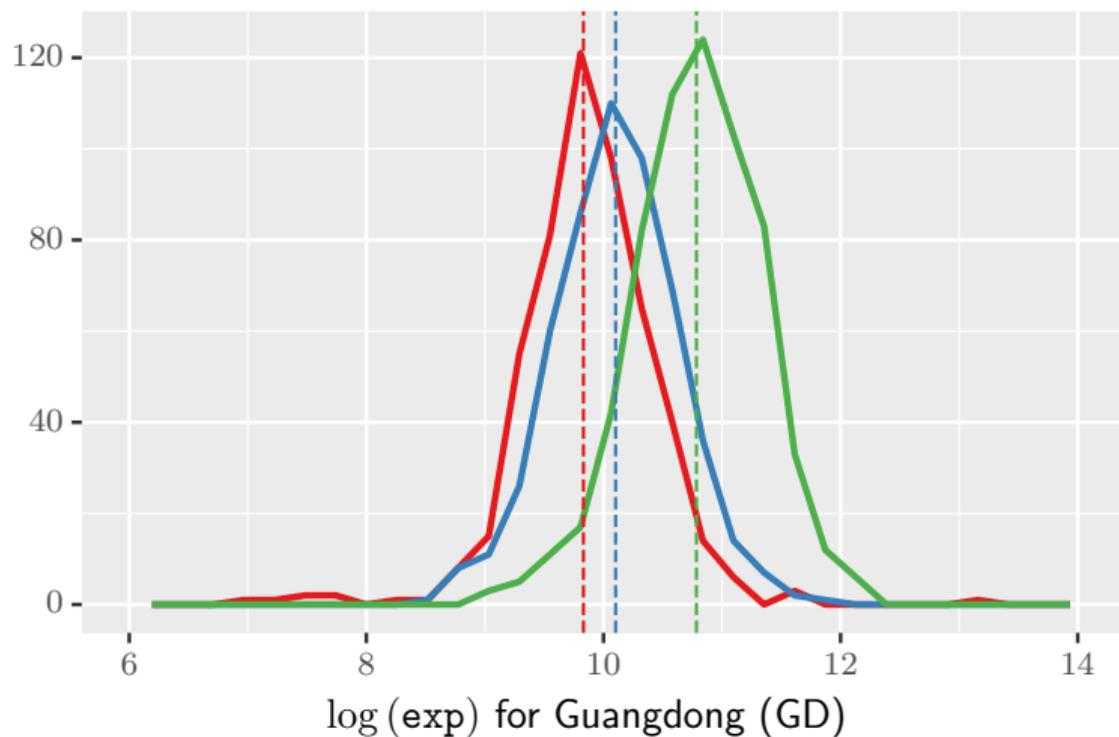
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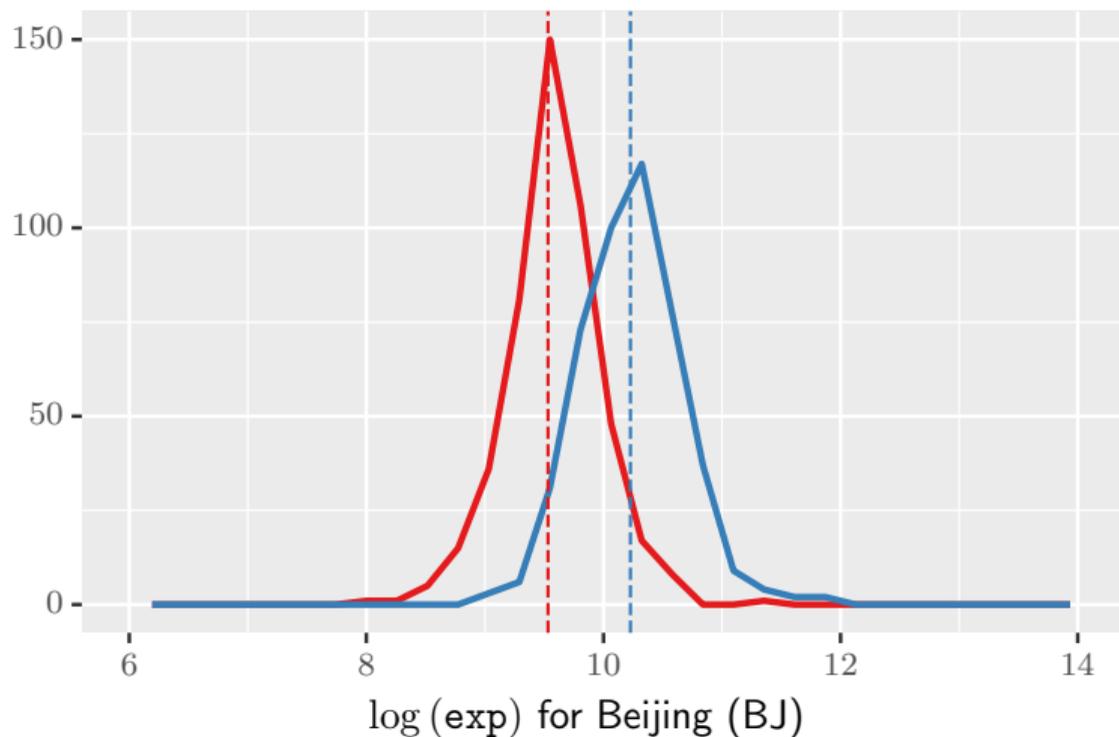
## Distribution of total household expenditure ( $x$ )



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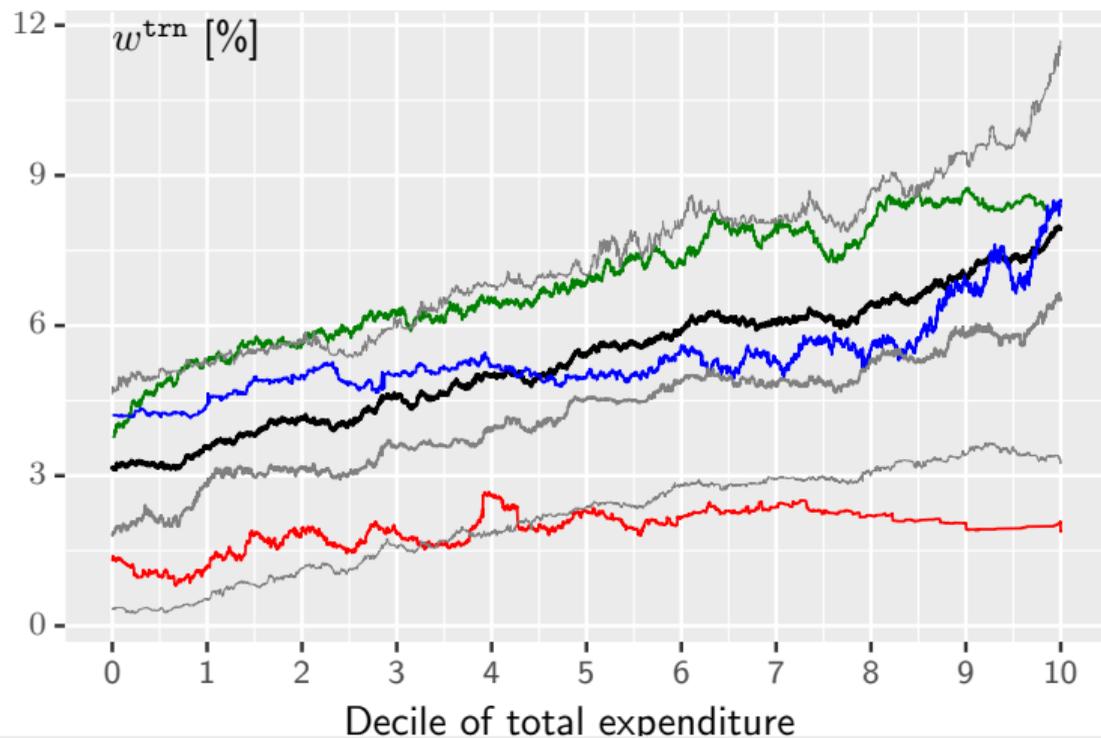


Income distribution shifts rightwards.

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# Raw $w^{\text{trn}}$ data: conditional means differ by year

—  $Q_1$ , median,  $Q_3$  — mean, 1995 — 2002 — 2007 — mean, all data



→ Control for unobserved, nationwide, time-varying confounders w/ year fixed effects.

**Household expenditures** ( $w^j, x$ ) from CHIP social science survey.<sup>10</sup>

**City-level attributes** ( $z$ ) from “China Premium Database” published by CEIC Data (CEIC).

- Aggregated provincial general & transport statistical yearbooks.
- Prefecture- and county-level annual series.

**Prices** ( $p$ ) from National Bureau of Statistics of China (NBSC).

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<sup>10</sup>Li et al. 2008; Luo et al. 2013.

## City-level measures — primary series from CEIC

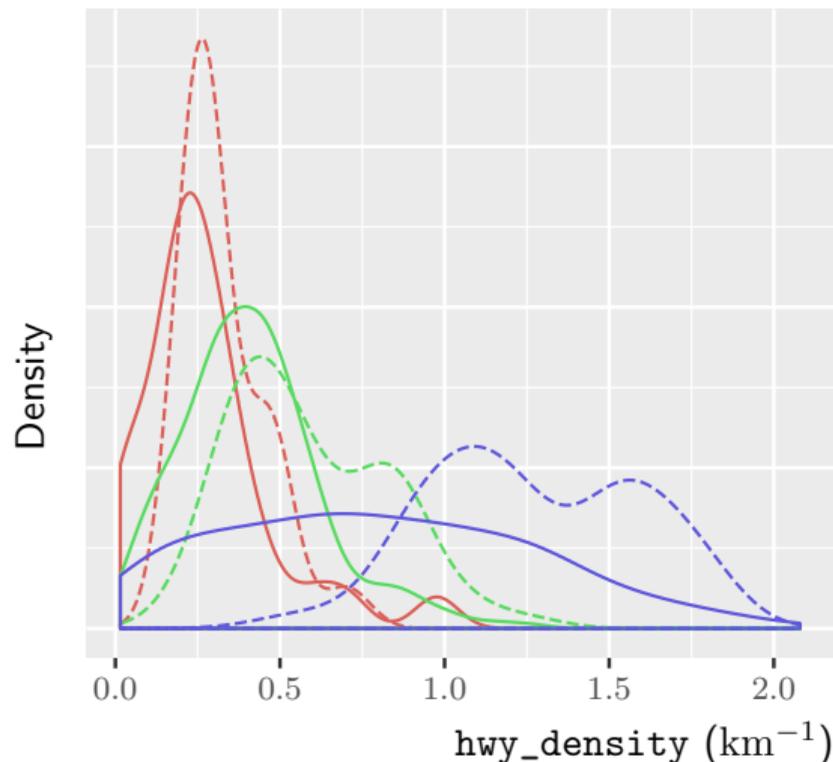
Name, <i>t</i>	Description	Unit	Source	No. of series
<b>area</b>	Land Area of Administrative Zone	$10^6$ m <sup>2</sup>	NBS	359
<b>gdp_cap</b>	GDP: per Capita	$10^3$ RMB/pers.	NBS	2235
<b>gdp</b>	GDP	$10^6$ RMB	NBS	2279
<b>hwy</b>	Highway: Length of Highway	$10^3$ m	NBS, MoT	358
<b>p_hwy</b>	Highway: Passenger Traffic	$10^6$ pers.	NBS, MoT	314
<b>p_rail</b>	Railway: Passenger Traffic	$10^6$ pers.	NBS	250
<b>pop</b>	Population	$10^3$ pers.	NBS	2382
<b>stock_bus</b>	No of Public Transit Vehicle: Bus and Trolley Bus	$10^3$ veh.	NBS	287
<b>stock_priv</b>	No of Motor Vehicle: Private Owned	$10^3$ veh.	NBS, MoT	325
<b>stock_rent</b>	No of Rental Vehicle	$10^3$ veh.	NBS	287
<b>wage_avg</b>	Average Wage	$10^3$ RMB/pers.	NBS	1699

NBS = National Bureau of Statistics; MoT = Ministry of Transportation

## City-level measures — derived & direct variables in models

Name, $t$	Description	Unit
<code>density</code>	Population density	$10^3$ pers./km <sup>2</sup>
<code>gdp_cap</code>	GDP: per Capita	$10^3$ RMB/pers.
<code>hwy_density</code>	Highway network density	1/km
<code>p_hwy_cap</code>	Passenger commercial road ridership per capita	$10^3$
<code>stock_bus_cap</code>	Stock of buses & trolley bus vehicles per capita	$10^{-3}$ veh./pers.
<code>stock_priv_cap</code>	Stock of private vehicles per capita	$10^{-3}$ veh./pers.
<code>stock_rent_cap</code>	Stock of rental vehicles per capita	$10^{-3}$ veh./pers.
<code>wage_avg</code>	Average Wage	$10^3$ RMB/pers.

# Distributions of city-level variables covered by CHIP obs/waves



Year

1995

2002

2007

Geo. units

All of China

Sampled by CHIP

Variation across & within households covered by CHIP.

→ Rapid change in conditions faced by households.

→ Statistical power for effects estimation.

→ Policy levers for government.

Household expenditures ( $w^j, x$ ) from CHIP social science survey.<sup>10</sup>

City-level attributes ( $z$ ) from “China Premium Database” published by CEIC Data (CEIC).

**Prices** ( $p$ ) from National Bureau of Statistics of China (NBSC).

- New code to scrape these from China NBS Data Explorer backend API.
- Quality of these data is good; or at least low likelihood of falsification (Holz 2013).

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<sup>10</sup>Li et al. 2008; Luo et al. 2013.

## Expenditure categories & price data series

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Category, <i>j</i>	Code	NBSC description
<b>food</b>	A090202	Consumer Price Indices (preceding year=100), Food
<b>clo</b>	A09020G	[...] Clothing
<b>trn</b>	A090213	[...] Transportation and Communication
<b>hou</b>	A09021N	[...] Residence
<b>ed</b>	A09021D	[...] Entertainment and Education
<b>dur</b>	A09020M	[...] Durable Consumer Goods.
<b>med</b>	A09020R	[...] Health Care and Personal Articles
<b>other</b>	A090201	Consumer Price Index (preceding year=100)

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Parametric (Moulton) correction for standard errors on clustered city-level variables.

All models contain both province- and year-fixed effects.

Names:

“**yR**” Model contains  $R$  powers of implicit utility,  $y$ .

“**+hh**” +4 household-level regressors (**age**, **educ**, **gender**, and **single**).

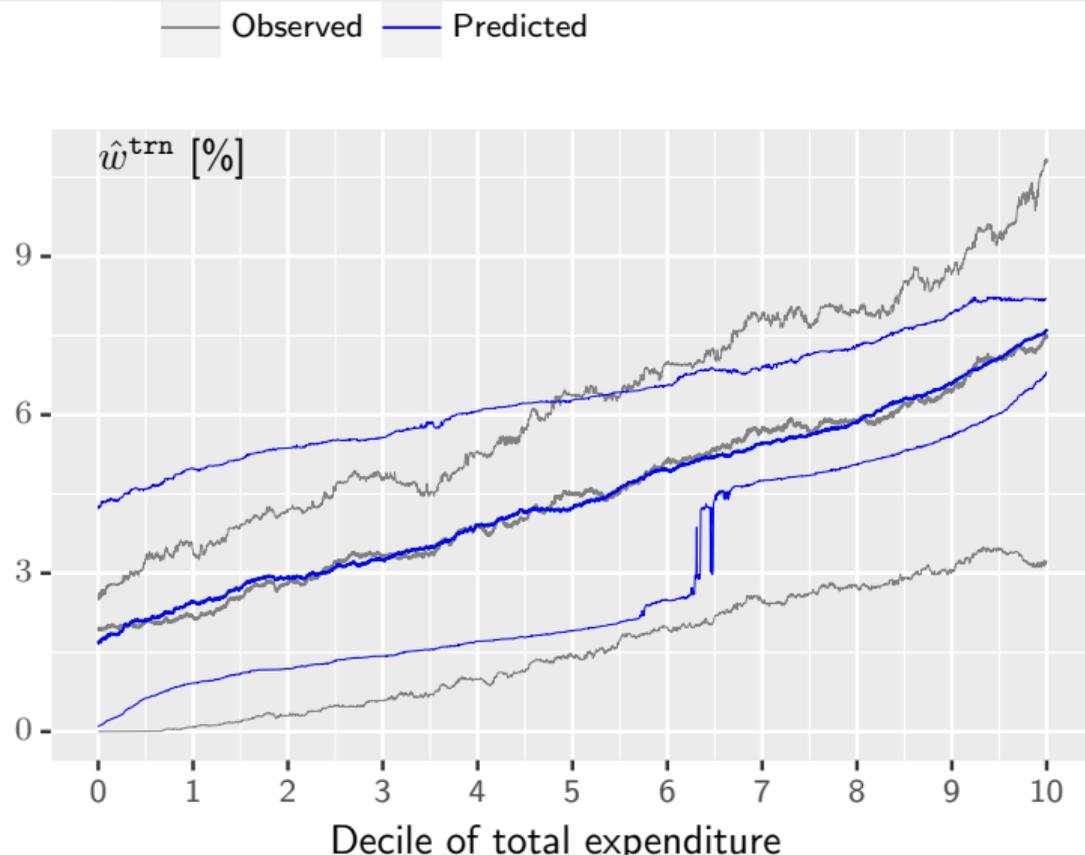
“**+city**” +8 city-level regressors.

## Results

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# Transport budget share rises from 1.6% to 7.5%

(model y3+hh)

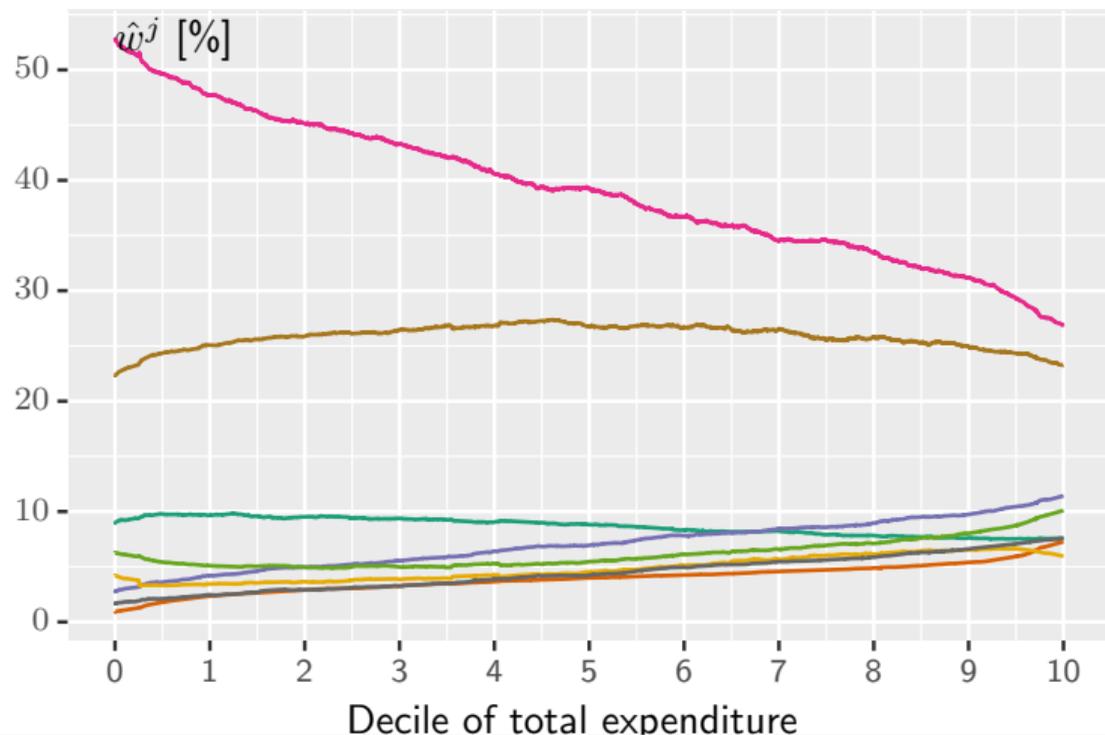


$w$ (%)	Note
Dai et al. (2012)	
5	1995
12.6	2005
26	2050 (proj.)
Caron et al. (2017)	
2.1	Gasoline
2.6	Transport
4.7	Total (2007)
2.9	Gasoline
6.1	Transport
9.0	Total (2030)
Marchetti (1994)	
3.4–4.2	US/DE w/o car
10–12	“ ” w/ car

# EASI captures varying shapes of budget share curves

(model y3+hh)

clo dur ed food hou med other trn



Significant estimates for  $y^0 \dots y^3$ 

(model y3+hh+city)

	food	clo	trn	hou	ed	dur	med
$\hat{\beta}_{u,0}^j$	-16.738** (7.564)	-8.979*** (3.337)	7.061*** (2.446)	-0.655 (3.178)	8.499* (4.540)	12.921*** (2.888)	63.820*** (3.645)
$\hat{\beta}_{u,1}^j$	33.043*** (3.049)	-2.543** (1.201)	-4.230*** (0.926)	14.599*** (1.316)	-10.374*** (1.902)	-3.638*** (1.138)	-22.163*** (1.451)
$\hat{\beta}_{u,2}^j$	-4.198*** (0.476)	0.474** (0.188)	0.650*** (0.145)	-2.482*** (0.206)	1.469*** (0.297)	0.381** (0.178)	2.649*** (0.227)
$\hat{\beta}_{u,3}^j$	0.139*** (0.022)	-0.019** (0.009)	-0.025*** (0.007)	0.116*** (0.010)	-0.052*** (0.014)	-0.005 (0.008)	-0.102*** (0.011)
$\hat{\beta}_{z,age}^j$	1.815*** (0.269)	-1.903*** (0.106)	-0.427*** (0.082)	-0.532*** (0.116)	-0.467*** (0.168)	0.006 (0.100)	1.083*** (0.128)
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

t-tests: \* = significant at 10% level    \*\* = 5%    \*\*\* = 1%

# Alternate model specifications → higher-order relationship of $w^{\text{trn}}$ to income

$y^3, y^4$  – significant in  $w^{\text{trn}}$  and for budget shares overall.

$y^5, y^6$  – adding higher powers eliminates significance  $\forall R$ .

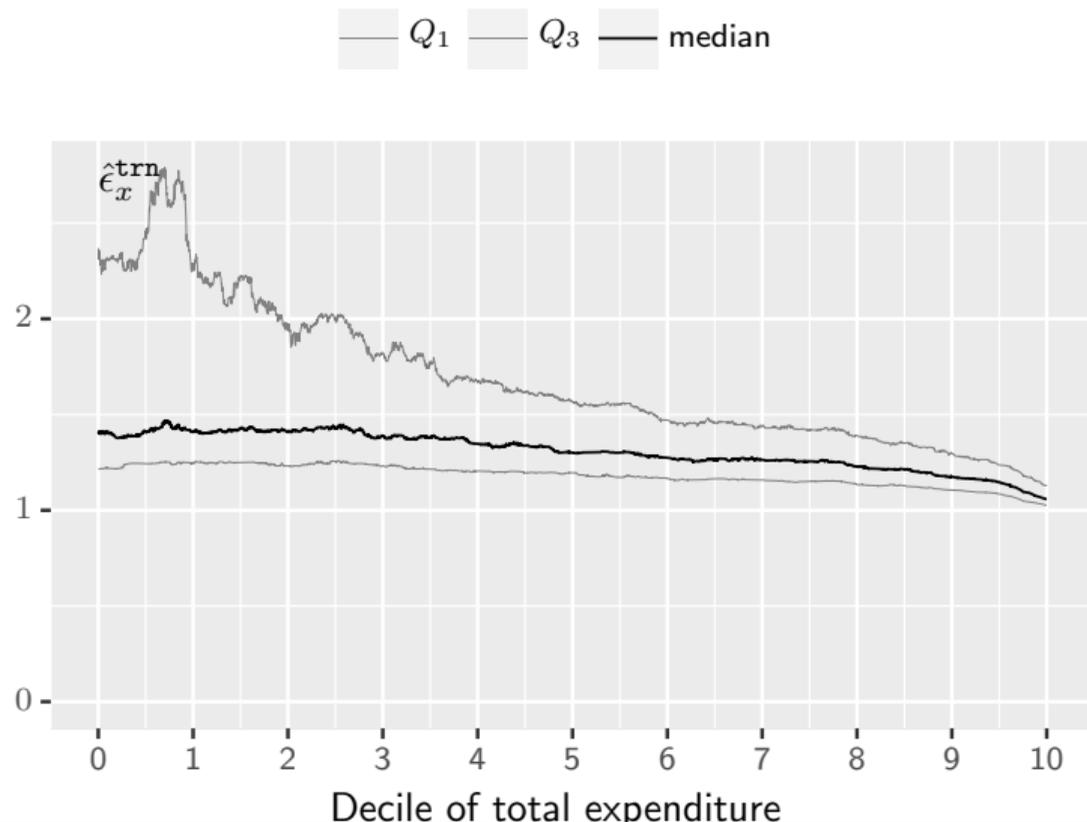
\* =  $t/F$ -stat significant at 10% level

\*\* = 5%

\*\*\* = 1%

	(1)	(2)	(3)	(4)	(5)
Model name	y3	y3+hh+city	y4+hh+city	y5+hh+city	y6+hh+city
Observations, $N$	17689	13357	13357	13357	13357
Household vars	–	4	4	4	4
Year fixed effects	–	·	·	·	·
Province fixed effects	–	·	·	·	·
Powers of (implicit) utility ( $t$ , or $t / F$ )					
Number included, $R$	3	3	4	5	6
0	***	***			
1	***	***			
2	***	***	**		
3	**	*** / ***	**		
4	–	–	*** / ***		
5	–	–	–	/	
6	–	–	–	–	/

# trn expenditure is elastic with respect to income



%ile of $x$	$\epsilon_x^{trn}$
7	1.47
50	1.30
100	1.06

Compare:

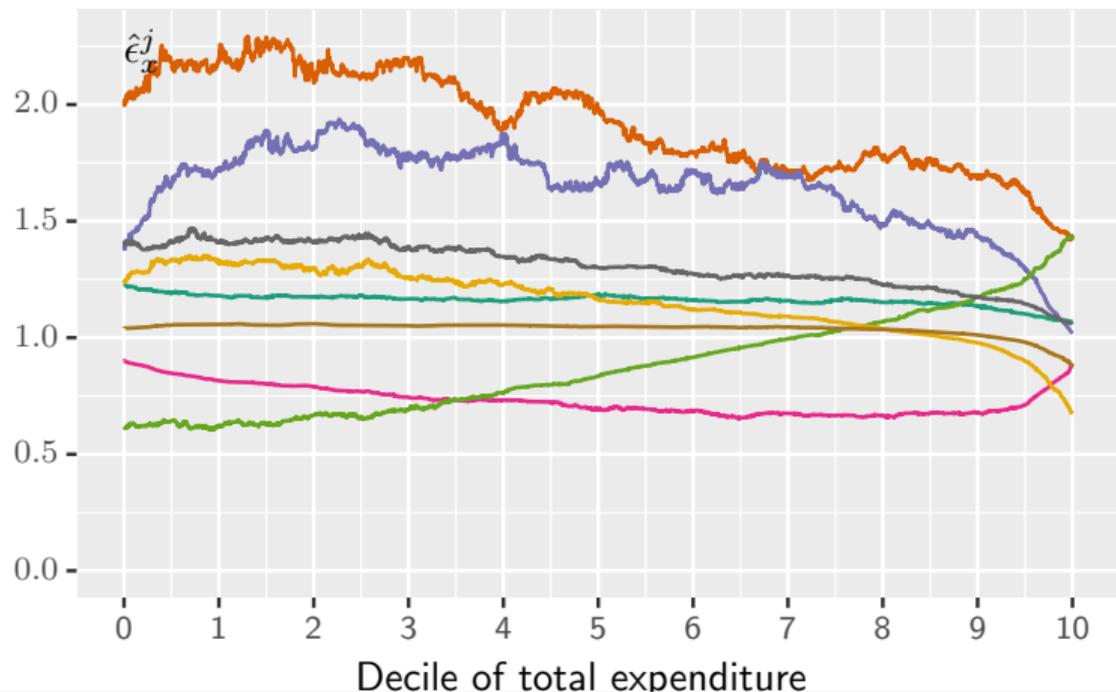
Wang, P. Zhou, and  
D. Zhou (2012)

Province	$\epsilon_x^{trn}$
GZ	1.2
TJ	1.7
BJ	2.4
SH	3.0
YN	4.2

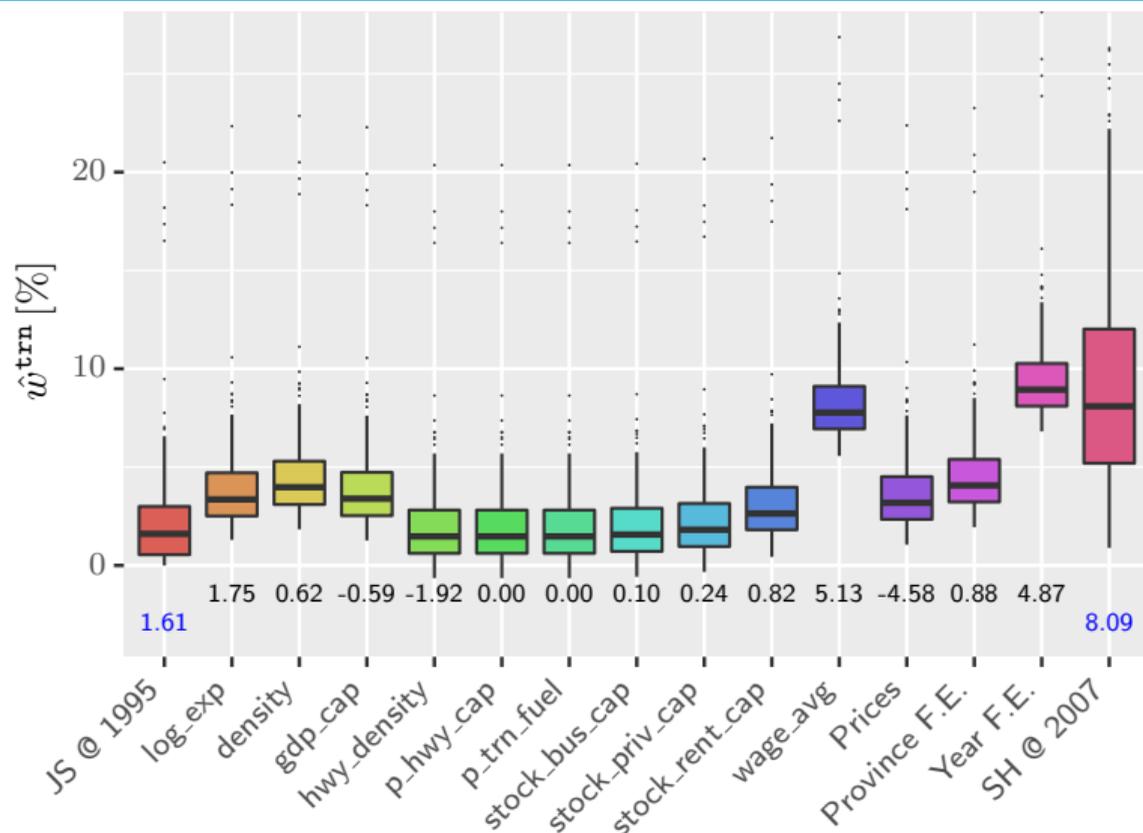
AIDS; aggregate data

# Elasticities of all expenditure categories with respect to income

clo dur ed food hou med other trn



# Shifts in budget share between Jiangsu 1995 and Shanghai 2007 households



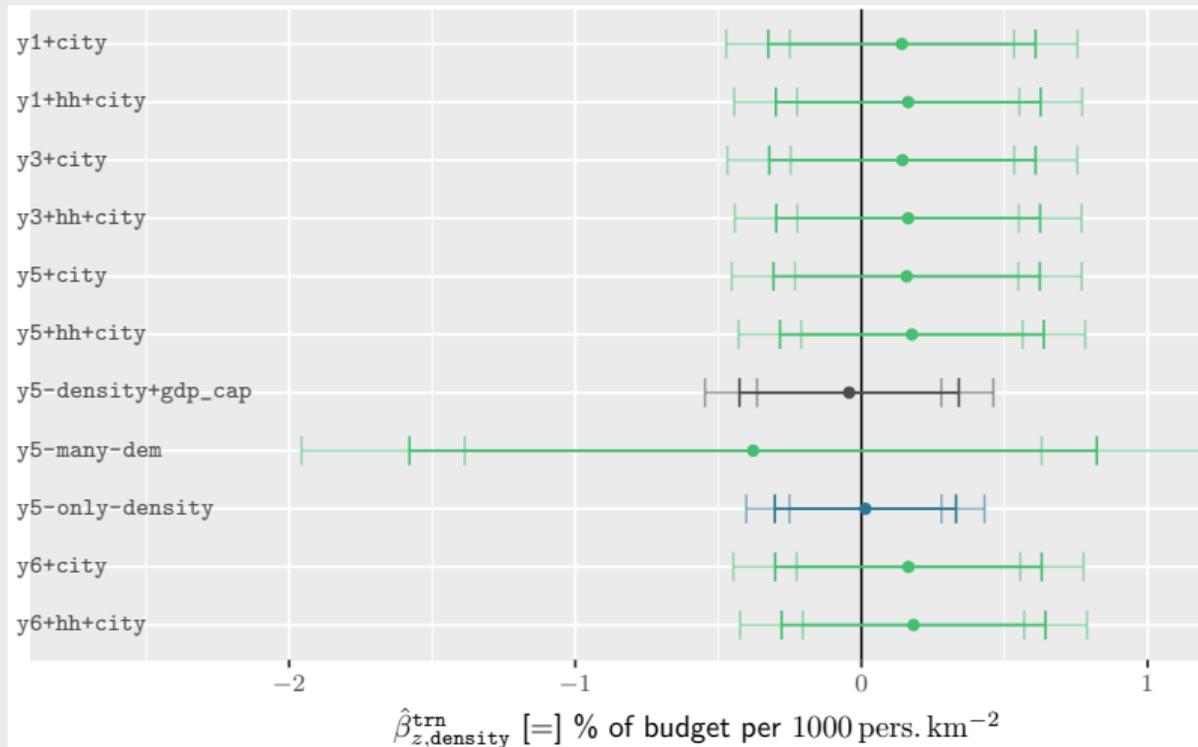
Blue: median  $w^{\text{trn}}$

Black: shifts  $\updownarrow$

Total expenditure ( $x$ ,  $\sim$ income) explains 27% of the gap between these groups of households.

Variables shifted from JS @ 1995  $\rightarrow$  SH @ 2007 distributions

# Local conditions affect budgets overall; but no estimates for $w^{\text{trn}}$ effects



Color:

$F$ -test of

$$\hat{\beta}_{z,t}^j = 0 \quad \forall j$$

Position:

90, 95, & 99% CIs for estimate.

Pr(>F)

● > 0.1

● < 0.1

● < 0.05

● < 0.01

“-only-var”: only var as a city-level regressor.

“-many-dem”: a larger set of city-level regressors.

New estimates of demand metrics:

- Transport budget share of 1.6 % to 7.5 % — broader range than in literature using provincial data, yet lower levels.
- Income-elasticity higher for total transport expenditure than in gasoline for the literature.
- Variation across households is smaller than in older literature using provincial aggregate data.

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# Findings

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$y^3$ ,  $y^4$  terms significant in EASI demand systems → demand varies in complex ways with income, beyond capacity of current formulations.

Relationship to measures of the built environment: significant associations explain a large share of budget, but parameter estimates await better data (endogeneity, precise measures).

**Not shown today:** cross-validation on CHIP provincial subsets → demand/BE relationship varies significantly across provinces.

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**Extensions:** Estimate flexible demands on:

- Other China survey data, e.g. China General Social Survey (CGSS) → convergent or divergent conclusions?
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Micro-simulation across Chinese provinces & cities → welfare impacts of transport policies, e.g. vehicle ownership restrictions.

Conclusions from the work:

- Reduce reliance on out-of-country precedents/relationships.
- Develop methods for overcoming local data limitations.
- More attention to understudied regions.

**Are expenditure relationships (“travel money budgets”) more likely to survive disruptive innovations** than...

- ...travel time budgets?
- ...growth/saturation curves of passenger-distance traveled?
- ...of vehicle ownership and usage?



Thank you!

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